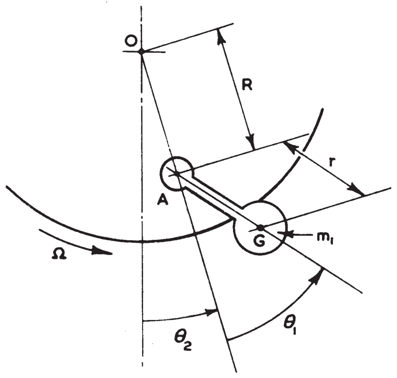
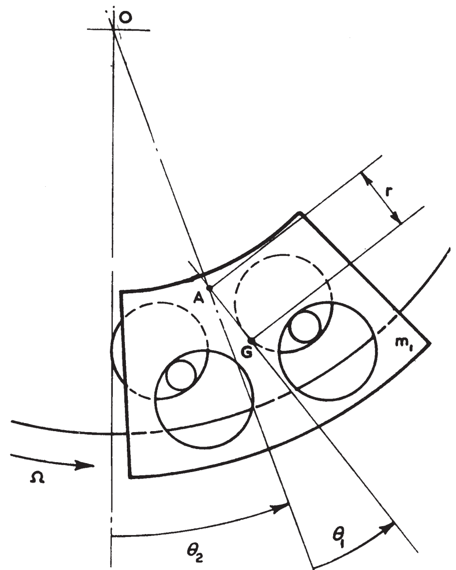
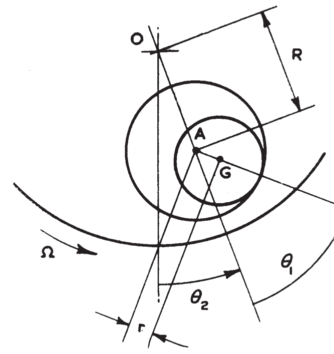
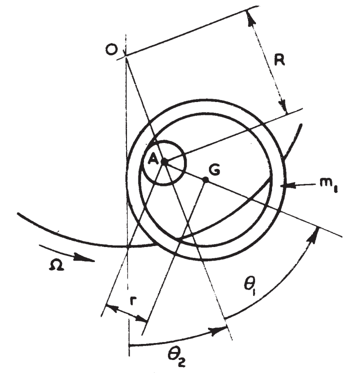
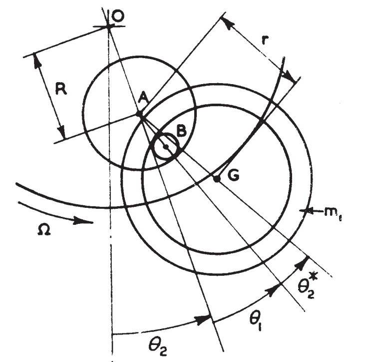
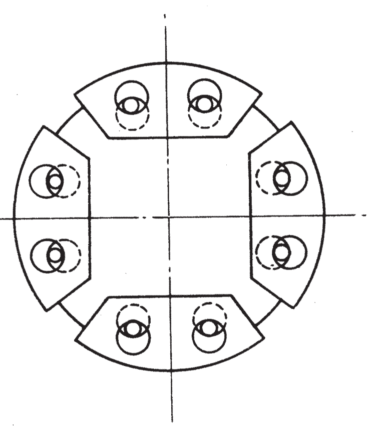
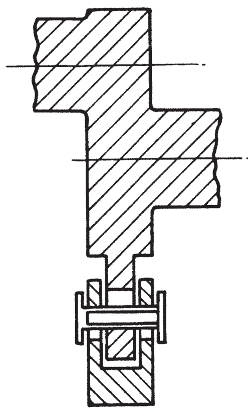
Various Types of Centrifugal Pendulum Detuners

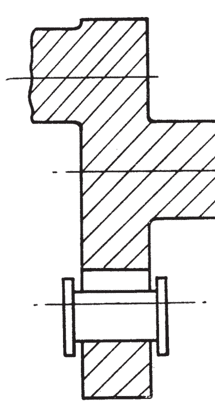
Notation: Ω = phase velocity of shaft rotation, $T_{(n)}$ = excitation torque (nth order critical), $m_1 = W_1/g$ = mass of pendulum, J_G = moment of inertia of m_1 about its centre of gravity G, n = order number of critical speed [vib./rev.], θ_2 = vibration amplitude of carrier (of inertia J_2). *With resonance tuning: $\theta_2 = 0$, for all pendulums considered.*

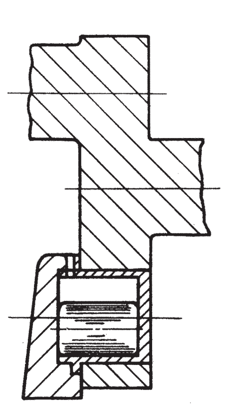
	Simple ('Mathematical') pendulum	'Bifilar' pendulum	Roller-type pendulum	Ring-type pendulum	Composite-type pendulum (roller and ring)
	$\overline{OA} = R$, $\overline{AG} = r$	$\overline{OA} = R$ (where A = effective point of suspension) $\overline{AG} = r = D - d$	$\overline{OA} = R$, $r = (D-d)/2$	$\overline{OA} = R$, $r = (D-d)/2$	$\overline{OA} = R$, $r \cong D - d$
					
		d = diameter of rollers D = diameter of holes	m_1 = mass of roller D = diameter of cavity d = diameter of roller A = centre of cavity	m_1 = mass of ring D = inner diameter of ring d = pin diameter A = centre of pin	m_1 = mass of ring D = inner diameter of ring and diameter of cavity d = roller diameter
Tuning ratio:	$n^2 = \frac{R}{r}$	$n^2 = \frac{R}{r}$	$n^2 = \frac{R}{r} \times \frac{1}{\left[1 + \frac{4J_G}{m_1 d^2}\right]}$	$n^2 = \frac{R}{r} \times \frac{1}{\left[1 + \frac{4J_G}{m_1 D^2}\right]}$	Two modes of vibration: (I) 'Rigid-pendulum' motion (with $\overline{ABG}$ = straight line, hence $\theta_2^* = 0$): $n_{(I)}^2 = R/r$ $\theta_1 = \frac{T_{(n)}}{m_1(R+r)\, rn^2\Omega^2}$
Vibration amplitude of pendulum (at resonance tuning):	$\theta_1 = \frac{T_{(n)}}{m_1(R+r)\, rn^2\Omega^2}$	$\theta_1 = \frac{T_{(n)}}{m_1(R+r)\, rn^2\Omega^2}$	$\theta_1 = \frac{T_{(n)}}{\left[m_1(R+r) - \frac{2J_G}{d}\right] rn^2\Omega^2}$	$\theta_1 = \frac{T_{(n)}}{\left[m_1(R+r) + \frac{2J_G}{D}\right] rn^2\Omega^2}$	(II) 'Anti-phase pendulums' motion: $n_{(II)}^2 = \left(1 + \frac{R}{r}\right)\left(\frac{m_1 D^2}{4J_G}\right)$ $\theta_1 = -T_{(n)} \Big/ \left[2J_G \frac{r}{D} n^2\Omega^2\right]$ $\theta_2^* = -2\theta_1$ *Note.* Usually, $n_{(II)} < n_{(I)}$; in practice only $n_{(I)}$ is used because in many cases $n_{(II)}$ is unstable, with excessive pendulum amplitudes.
Response to any other nth order excitation torque $T_{(n)}$: Vibration amplitude of pendulum m_1:	$\theta_1 = \frac{(R/r) + 1}{1 - \frac{R}{rn^2}} \times \theta_2$	$\theta_1 = \frac{(R/r) \times 1}{1 - \frac{R}{rn^2}} \times \theta_2$	$\theta_1 = \frac{1 + (R/r) - (2J_G/m_1 dr)}{1 + \frac{4J_G}{m_1 d^2} - \frac{R}{rn^2}} \times \theta_2$	$\theta_1 = \frac{1 + (R/r) + (2J_G/m_1 Dr)}{1 + \frac{4J_G}{m_1 D^2} - \frac{R}{rn^2}}\, \theta_2$	$\theta_1 = -\frac{(R/r) + 1}{1 - \frac{R}{n^2 r}} \times \theta_2 - \frac{1}{2}\theta_2^*$ $\theta_2^* = \frac{-D/r}{1 - \frac{(R/r)+1}{n^2} \times \frac{m_1 D^2}{4J_G}} \times \theta_2$
Vibration amplitude of carrier J_2:	$\theta_2 = T_{(n)}/[K_2 - \omega^2 J_2 - \omega^2 J_{P\,\mathrm{eff.}}]$, where $J_{P\,\mathrm{eff.}} = m_1(R+r)^2 \times \left[1 + \frac{1}{\frac{R}{rn^2} - 1}\right]$	$\theta_2 = T_{(n)}/[K_2 - \omega^2 J_2 - \omega^2 J_{P\,\mathrm{eff.}}]$, where $J_{P\,\mathrm{eff.}} = J_G + m_1 \frac{(R+r)^2}{1 - \frac{r}{R} n^2}$	$\theta_2 = T_{(n)}/[K_2 - \omega^2 J_2 - \omega^2 J_{P\,\mathrm{eff.}}]$, where $J_{P\,\mathrm{eff.}} = J_G + m_1(R+r)^2 - \frac{m_1\left(R + r - \frac{2J_G}{m_1 d}\right)^2}{1 + \frac{4J_G}{m_1 d^2} - \frac{R}{n^2 r}}$	$\theta_2 = T_{(n)}/[K_2 - \omega^2 J_2 - \omega^2 J_{P\,\mathrm{eff.}}]$, where $J_{P\,\mathrm{eff.}} = J_G + m_1(R+r)^2 - \frac{m_1\left(R + r + \frac{2J_G}{m_1 D}\right)^2}{1 + \frac{4J_G}{m_1 D^2} - \frac{R}{n^2 r}}$	$\theta_2 = T_{(n)}/[K_2 - \omega^2 J_2 - \omega^2 J_{P\,\mathrm{eff.}}]$, where $J_{P\,\mathrm{eff.}} = \frac{m_1(R+r)^2}{1 - \frac{n^2 r}{R}} + \frac{J_G}{1 - \frac{r}{R+r} \times \frac{4J_G}{n^2 m_1 D^2}}$
Alternative designations:		Sarazin pendulum Chilton pendulum Taylor pendulum	Salomon pendulum	Salomon pendulum	'Duplex' pendulum
Other remarks:		All holes of equal radius			Above formulae are strictly applicable when roller inertia $J_{\mathrm{roll.}} \cong \frac{1}{4} m_{\mathrm{roll.}} \times d^2$, where $m_{\mathrm{roll.}}$ = mass of roller

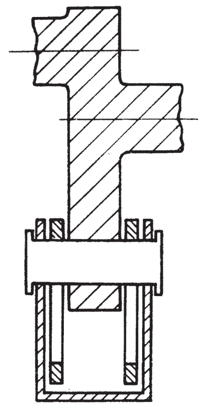
Examples of detuner arrangements:

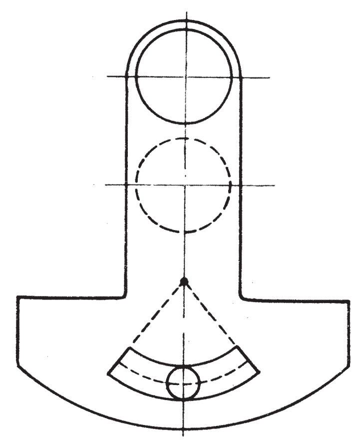

Bifilar type

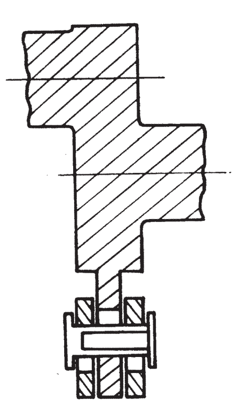

Bifilar type


Roller type


Roller type


Ring type


Roller type (or ball type)


Composite (roller and rings) type